

## ASTRONOMY CATS

GINA BRISSENDEN, EDWARD E. PRATHER AND  
CHRIS IMPEY

*University of Arizona*  
*Steward Observatory*  
*933 N. Cherry Avenue*  
*Tucson AZ 85721, U.S.A.*  
gbrissenden@as.arizona.edu  
eprather@as.arizona.edu  
cimpey@as.arizona.edu

**Abstract.** The Center for Astronomy Education's (CAE's) NSF-funded Collaboration of Astronomy Teaching Scholars (CATS) Program is a grass-roots multi-institutional effort to increase the capacity for astronomy education research and improve science literacy in the United States. Our primary target population is the 500,000 college students who each year enroll in an introductory general education (a breadth requirement for non-science majors) Earth, Astronomy, and Space Science (EASS) course (Fraknoi 2001, AGI 2006). An equally important population for our efforts is the individuals who are, or will be, teaching these students.

In this chapter, we will briefly discuss the goals of CAE and CATS, the varied personnel that make up the CATS collective, the diverse projects we've undertaken, and the many challenges we have had to work through to make CATS a success.

### 1. Goals of CAE and CATS

CAE in Steward Observatory at the University of Arizona, lead by Ed Prather and Gina Brissenden, is devoted to improving teaching and learning in general education EASS courses by conducting investigations into students' beliefs and reasoning difficulties, and instructors' implementation difficulties related to teaching EASS. The results of this work are used to inform the development of proven instructional strategies and assessment materials for use in the EASS classroom. These research-validated

instructional strategies and assessment materials are prominently featured during our professional development CAE *Teaching Excellence Workshops* for general education EASS instructors (Prather *et al.* 2009 and the references therein). The goal of these professional development workshops is to increase the pedagogical content knowledge of instructors and improve the effectiveness of their classroom implementation abilities.

To create sustainability and broaden the national impact and scope of our work, the leadership of CAE, in cooperation with other leaders in astronomy education and research (Chris Impey, Univ. Arizona and Kevin Lee, Univ. Nebraska), developed the NSF-funded Collaboration of Astronomy Teaching Scholars (CATS) Program. The primary goals of CATS are to:

1. increase the number of general education EASS instructors conducting fundamental research in discipline-based education;
2. increase the amount of research-validated curriculum and assessment instruments available for use in general education EASS courses; and
3. increase the number of instructors developing and conducting their own CAE *Teaching Excellence Workshops*.

## 2. The CATS Collaborative

The broader CAE community is approximately 3000 members strong and growing. But creating a community this large does not happen immediately or effortlessly. How this community came to be is probably best understood by stepping back in time to look at pivotal milestones along the way.

It was our desire to foster a population of EASS instructors who cared deeply about the learning occurring in their classes, and who were motivated to conduct research on the effectiveness of their own instruction. We also wanted to create a larger community of instructors that would lend support, advice, council, and wisdom, to each other.

We knew the instructors who would be willing to do their own research would also have spent a few semesters trying one or more of the interactive learning strategies in their classroom, and would be eager to know how well it was working. These same instructors were also often active participants in our online academic community of practice listserv, [AstroInrner@CAE](mailto:AstroInrner@CAE).

However, before we could expect inexperienced EASS instructors to try new curriculum in their class, they would first need to feel confident about their ability to effectively implement the curriculum in their courses. It was for this reason that we created our CAE *Teaching Excellence Workshop* series, which debuted in 2004. The participation-based workshops have provided EASS instructors with the experiences they needed to become familiar with best practices when using classroom proven curriculum (Prather

& Brissenden 2009). All workshop participants were also invited to join `AstroInrner@CAE` in an effort to expand their professional development experience beyond the workshop setting. To date, we have conducted hundreds of workshops, in over half of the US states, Puerto Rico, Canada, and France.

Our workshops have been attended by thousands of current and future (grad students and postdocs) college EASS instructors, as well as hundreds of middle school and high school teachers. The success of these workshops has been greatly facilitated by the strong relationships CAE has developed with professional societies such as the American Astronomical Society, the American Association of Physics Teachers, and the Astronomical Society of the Pacific. These societies help promote our workshops, as well as provide venues for them to be held. Their endorsement of our workshops also provides a certain *gravitas* to the notion that working to become a better instructor is valued. A surprising outcome to us is that about 25% of our Tier I (or “introductory”) workshop attendees participate in a second Tier I workshop. And of these 2-time Tier I participants, about 35% attend a Tier I workshop three or more times.

Before we could create our CAE *Teaching Excellence Workshops*, designed to help train instructors to become effective implementers of active engagement instructional strategies, so they would become motivated to do research, we first had to develop and validate a suite of instructional strategies and assessment materials to get the whole thing started – which we began way back in 2000 (Prather *et al.* 2009 and the references therein).

Over the last decade, through CAE’s programmatic evolution described above, we had grown our community of practice to approximately 3000 members, and were finally ready to select scholars to participate in the *CATS Fellowship* program. The *CATS Fellowship* program provides leadership opportunities for instructors who have made significant pedagogical contributions to the CAE *Teaching Excellence Workshops* and who have consistently participated in and elevated the scholarly nature of discussions on the `AstroInrner@CAE` `listserv`. It is through the collaborative work done by *CATS Fellows* that the goals of the CATS program would be achieved.

There are over 50 *CATS Fellows* involved in one or more of the many CATS collaborative research and professional development projects. These *CATS Fellows* represent senior and junior faculty, adjunct instructors, post-doctoral researchers, as well as graduate and undergraduate students. They come from 4-year institutions that primarily focus on research; from 4-year liberal arts colleges; and from 2-year community colleges. The *CATS Fellows* also represent an incredible geographical diversity (Fig. 1). Through the geographical and experiential diversity represented by the participants

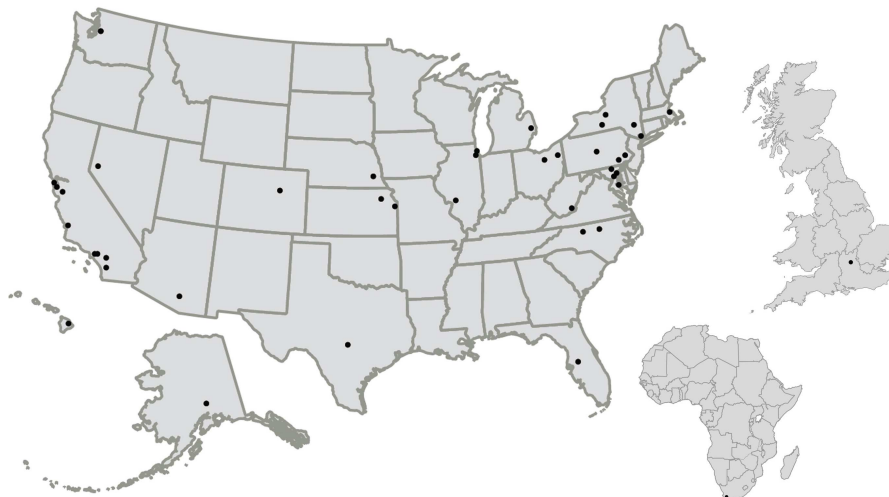


Figure 1. Dots represent the location of a *CATS Fellow*, or group of *CATS Fellows*, who span the United States, Canada, England, & South Africa.

in the *CATS Fellows* program, we have substantially increased the likelihood that the voices of all stakeholders in the EASS teaching and learning community are being heard and their needs met.

### 3. Our Diverse Projects

When we wrote our grant to the NSF Course Curriculum and Laboratory Improvement (CCLI) Phase III Centers Program to create CATS, we had already identified several projects we believed were necessary to help move the college general education EASS teaching community forward. Our decisions as to which instructional strategies and assessment tools were in need of development, and which research investigations should be pursued, came from conversations with participants from the *CAE Teaching Excellence Workshops*, from the input of leaders from EASS professional societies, and from discussions occurring on our [Astrolrner@CAE](mailto:Astrolrner@CAE) academic listserv. We also informed these decisions from the outcomes of the Physics Education Research community that were positively impacting that community to improve teaching and learning in physics (McDermott & Redish 1999 and the references therein). The particular interests of individuals within the broader CAE community who would become our *CATS Fellows* identified additional new directions for CATS collaborative research and professional development.

Following is a small sample of the research projects and professional

development programs that highlight the collaborative nature of CATS, along with some of our research results. Our hope is that this sample helps to demonstrate a bit more about the complexity of CATS:

*3.1 An investigation into the teaching and learning that occurs in reformed college general education EASS courses using the Light and Spectroscopy Concept Inventory (LSCI)*

Perhaps the largest of the CATS research projects involved pre- and post-instruction testing of approximately 5000 students, from over 70 individual classes, taught by nearly 40 different instructors at more than 30 different colleges. Students were asked to answer the 26 conceptual questions presented in the Light and Spectroscopy Concept Inventory (Bardar *et al.* 2007). In addition, students were asked to complete 15 demographic questions. Phase I of our analysis involved an investigation into the relationships between class sizes, type of institutions, amount of course time spent using interactive learning strategies, and course-averaged student learning gains. Our findings have provided important insights as to which of these factors correlates with students' learning. We found that all general education courses start with approximately the same level of content understanding related to the topics of the LSCI (pre-instruction scores =  $24\% \pm 2\%$ ).

Much to our surprise we found that the class-averaged normalized gain scores were independent of class size or type of institution – demonstrating that students' achievement is possible no matter where you go to school or how big (or small) your class. We found that statistically, classes with higher levels of interactive engagement ( $IAS > 25\%$ ) on average did much better at improving student understanding. However, there were several classes that had a significant amount of class time dedicated to the use of interactive teaching methods but also had very little change in student achievement (Figs. 2-4). This result starts to illustrate how critical an instructor's implementation ability is to the success of a classroom, even when proven instructional strategies are being used (Prather *et al.* 2009 and the references therein)!

Phase II of this work focused on the student responses to our 15-question demographic survey. A multivariate regression analysis was conducted to determine how ascribed characteristics (personal, demographic and family characteristics), achieved characteristics (academic achievement and student major), and the use of interactive learning strategies are related to the individual student learning gains in these classes. The results show dramatic improvement in student learning with the increased use of interactive learning strategies even after controlling for individual characteristics. In addition, we found that the positive effects of interactive learning strategies apply equally to men and women, across ethnicities, for students with all levels of prior mathematical preparation and physical science course ex-

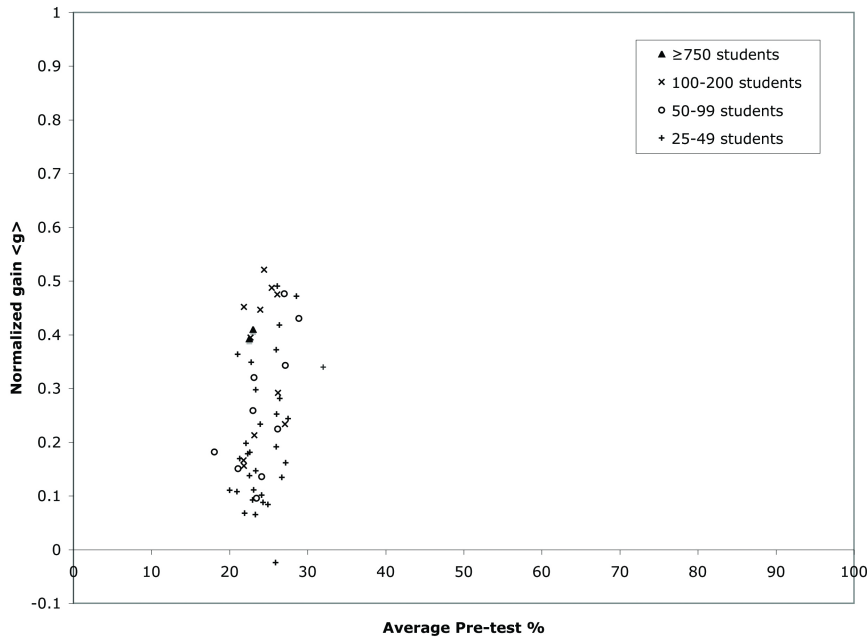


Figure 2. This graph displays the class-averaged normalized gain  $\langle g \rangle$  score vs. the class-averaged pre-test score identified by class size. Note that the averaged pre-test score is  $24\% \pm 2\%$  for all classes regardless of class size and that it is possible to achieve higher learning gains regardless of class size.

perience, independent of GPA, and regardless of primary language. These results powerfully illustrate that all students can benefit from the effective implementation of interactive learning strategies (Rudolph *et al.* 2010).

Phase III is an ongoing investigation using Item Response Theory to independently analyze changes in students' inherent reasoning abilities, and to determine the inherent difficulty and discrimination of the items in the LSCI itself.

Beyond the 70 instructors and 5000 students that contributed to this work, the three phases of this investigation have been the collaborative efforts of 4 faculty members, 2 graduate students, and 7 undergraduate research assistants from 4 different universities and colleges. A major component of one dissertation in Astronomy Education Research has come from this work.

### 3.2 An investigation of the conceptual and reasoning difficulties students have with learning cosmology, and the effectiveness of a Lecture-Tutorial approach to teaching cosmology

Over the past three years more than 10 instructors from as many different institutions have worked together on an investigation into students'

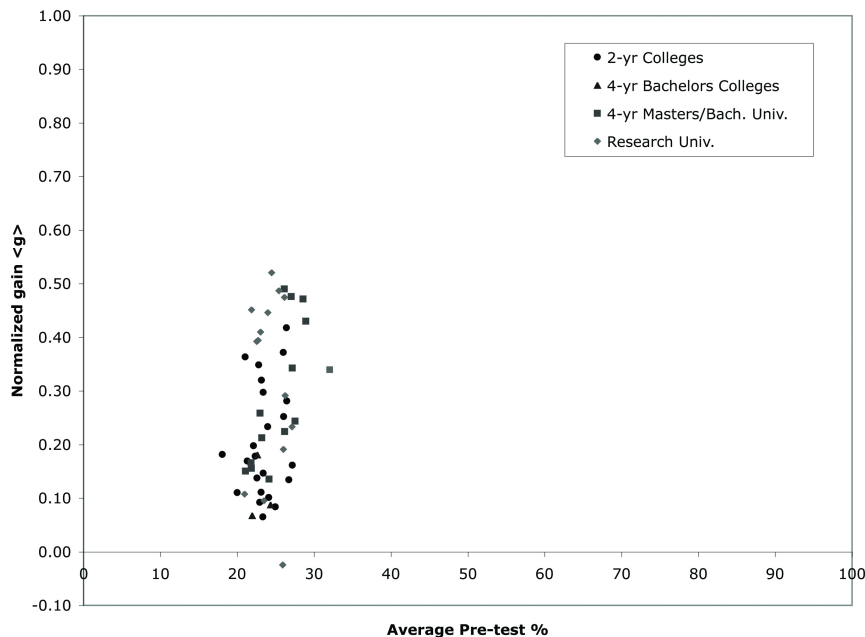
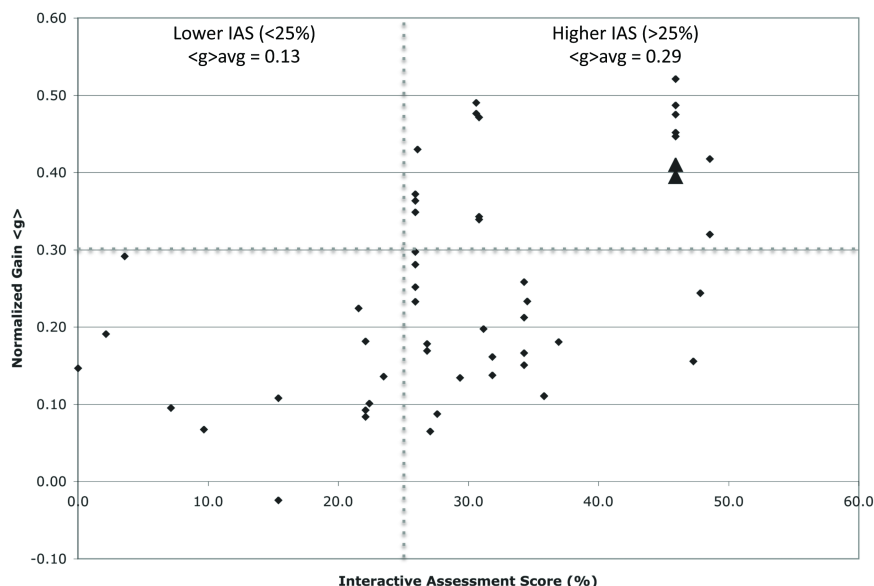


Figure 3. This graph displays the class-averaged normalized gain  $\langle g \rangle$  score vs. the class-averaged pre-test score identified by type of institution. Note that the averaged pre-test score is  $24\% \pm 2\%$  for all classes regardless of type of institution and that it is possible to achieve higher learning gains regardless of type of institution.

conceptual and reasoning difficulties in cosmology. To date, we have analyzed the written responses to a set of open-ended conceptual questionnaires from over 2000 students enrolled in classes at institutions all across the United States. The research questions investigate students' ideas on the Big Bang, the expansion and evolution of the Universe, and the evidence for dark matter. The findings from these investigations informed the development of a new suite of cosmology Lecture-Tutorials that are designed to increase students' understanding of these commonly taught cosmology topics. These Lecture-Tutorials have gone through several semesters of classroom testing in an iterative process to assess their effectiveness on student learning and to address the challenges to implementation brought up by the *CATS Fellows* who are trying them out in their classrooms. Ongoing systematic research has provided significant evidence to document that these new Lecture-Tutorials help students achieve larger learning gains than lecture alone over these challenging cosmology topics.

*3.3 Development and validation of the Question Complexity Rubric (QCR) for use with the creation of a national archive of Think-Pair-Share (TPS) questions*



*Figure 4.* This graph displays the class-averaged normalized gain  $\langle g \rangle$  score vs. the class's Interactive Assessment Score (% of class time taught interactively). Note that only classes with an IAS  $>25\%$  were able to achieve normalized gain  $\langle g \rangle$  scores above 0.30 and that there is a statistically significant difference in learning gains between the Lower IAS classes ( $<25\%$ ) and Higher IAS classes ( $>25\%$ ). Also note that simply because a class had an IAS  $>25\%$  was no guarantee of higher gains.

This project will generate a community-based national archive with hundreds of topically and hierarchically sorted, cognitively-challenging questions that are intended to supplement an instructor's implementation of TPS or for other assessment purposes (i.e. exams and homework) for use in EASS classrooms. In addition, this project is developing and validating the Question Complexity Rubric (QCR). The QCR is being created so that members of the EASS teaching and learning community will have a tool that allows them to assist us with ranking questions in this archive, based on the item's conceptual complexity and intellectual rigor. The online question archive system provides users with the utility to (1) use the QCR to score questions, (2) search for and download questions based on topic and/or QCR score, and (3) add their own questions to the archive. Early results involving more than 20 *CATS Fellows* established a set of calibration questions that are used to determine the effectiveness of the QCR. Pilot studies found that participants scored the calibration questions identically 70% of the time, and were within one QCR score of the item average

for 96% of all calibration questions. This work is ongoing and has seen a dramatic increase in participation from the greater CAE community.

### *3.4 Development and validation of the Solar System Concept Inventory (SSCI)*

The SSCI has been developed to assess students' conceptual and reasoning abilities regarding topics commonly taught in a college general education solar system course. The topics included on the SSCI were selected through a collaborative process involving several prominent planetary scientists from around the US, who identified the key concepts most commonly addressed in a solar system course taught at the general education level. SSCI topic domains include formation mechanisms, planetary interiors, atmospheric effects, and the properties of small solar system bodies. National multi-institutional field-testing has been going on for three years and has involved nearly 2500 students and 17 instructors from 10 different institutions. After each round of testing, a group of instructors from multiple institutions around the country worked together to analyze the data and revise or eliminate underperforming questions. Each question was examined using a combination of point-biserial (discrimination), percent correct (on the pre-test and post-test), and item difficulty to determine if the question was properly differentiating students' understanding while also ensuring the question was not too conceptually easy or difficult to answer. The final version of the SSCI is now available and being used to assess students' understanding in many classrooms across the US.

### *3.5 An investigation into participant conceptual understanding of science topics related to investigations of Citizen Science (CS)*

In the US, Citizen Science (CS) is an increasingly popular and very efficient way to help scientists with the reduction and analysis of data. CS activities provide members of the public with raw data and asks them to identify, label, categorize and sort science mission data so that scientists can continue their research using refined data-sets. Zooniverse is an institution that creates CS programs. Our international collaboration with Zooniverse is currently running two assessment programs designed to investigate whether there is a connection between the level of participation in Zooniverse Citizen Science activities and the development of conceptual understanding of the topics and tasks addressed in the CS activity.

Beginning efforts focused on the creation of two multiple-choice concept inventories designed in collaboration with mission scientists from the Sloan Digital Sky Survey (SDSS) and Lunar Reconnaissance Orbiter (LRO) and other content experts. One inventory is designed to investigate students' understanding of concepts related to the properties of galaxies, and the second instrument focuses on students' understanding of lunar cratering.

We have analyzed nearly 5000 responses from over 3500 users. The low-level participants, defined as participants who have tagged and labeled fewer than 100 images, received an average score of 41% on the Lunar Cratering Concept Inventory whereas high-level participants, those who processed over 600 images, score an average of 58%. While the initial results show significant differences between low-level participants and more experienced users, this work is ongoing and will begin using different methodologies of participant sampling and data analysis.

### *3.6 A long-term study of science literacy and attitudes toward science among non-science majors*

Over the last 20 years we have gathered over 10,000 questionnaires from students in general education classes at CAE's home institution. The questions come from an instrument used by the National Science Foundation to test basic scientific knowledge. Along with a standardized measure of "science literacy," the instrument has students respond to statements about science, technology, and pseudoscience on a Likert scale. The rich data set has allowed powerful statistical analyses of relationships between science knowledge and attitudes towards science. Overall, there is little gain in science literacy during an undergraduate career, spanning 2-3 general education science classes. Moreover, beliefs in pseudoscience are poor indicators of science literacy, indicating that non-scientific thinking persists alongside science knowledge. Factor analysis also shows little correlation between religious beliefs and science literacy.

This work is being extended through a mixed-methods study that uses longitudinal assessment data of student combined responses to several different concept inventories and science literacy surveys along with student one-on-one interview data. This research program elicits the input of the broader EASS teaching community about their own beliefs and attitudes about what is important for general education students to understand about the nature of science and the role in society. This multi-year, multi-institutional work will inform our understanding of how different instructional environments affect students' science literacy, their attitudes and beliefs about learning science, their thoughts on the role of science in society, and the ability of EASS courses to improve students' critical reasoning and evidence-based reasoning abilities.

### *3.7 A Situated Apprenticeship Approach to Professional Development*

Over the past several years members of CAE and the *CATS Fellows* program have provided *Teaching Excellence* professional development workshops to more than 2000 current and future EASS faculty (grad students and postdocs). The goal of these workshops is to provide participants with training in best practices for the effective implementation of

interactive learning strategies. What makes these intensive two-day, 16-hour workshops particularly unique is that participants are required to actively practice their teaching while the other workshop participants evaluate the implementation of the person teaching. This active-engagement and participation-based professional development framework is called Situated Apprenticeship (Prather & Brissenden 2009). There is now a cadre of more than 10 *CATS Fellows* who serve as co-presenters during the *CAE Teaching Excellence Workshops* held at national meetings. In addition a group of *CATS Fellows* have created five *CAE Regional Teaching Exchange* programs designed to expand the efforts of CAE and CATS to instructors in their part of the country.

#### 4. Challenges and Making It Work

Accomplishing the goals of the CATS program has required developing new models for collaborative, discipline-based research. While CAE, in Steward Observatory at the University of Arizona, is the activity hub of CATS, CATS is made up of over 50 collaborators, spread geographically across the country. They run the gamut of experience in education research from undergrads to tenured faculty. Several of our CATS projects have been, and are, the subject of PhD dissertation research as well as undergraduate research projects.

In the United States, we have an expression to describe the difficulty of getting a group of people to stay focused working together on a task all the way to completion: “It’s like herding cats.” Given the number of collaborators involved in CATS, the range of research experience, and the number of projects going on simultaneously, there probably isn’t a better phrase to describe what CATS has felt like. Yet, one of the most rewarding aspects of our collaboration has been the degree to which everyone in CATS has (in US baseball terms) “stepped up to the plate” and generously contributed their valuable time and resources to ensure the success of the diverse and challenging research and professional development programs undertaken.

One major challenge we have faced in coordinating CATS has been to keep each project collaborator working in unison and remain continuously engaged. In addition to their CATS responsibilities, each participant typically has other research, teaching, academic, departmental, and university responsibilities. These many other demands make effective communication and adherence to meeting and project deadlines difficult yet extremely important. Frequent collaborative team meetings held in person, or virtually via phone conference calls, Skype, and the like are key to keeping team members engaged, focused, well informed and on task. Frequent team meetings serve to establish participant responsibilities and deadlines, help

to inform members as to where they are falling behind, and identify potential roadblocks, which might stand in the way of progress. There is also the successful planning and executing of workshops, national and international meeting planning, writing timely research articles, etc. Finally, you and your collaborators will have additional questions related to executing research protocols, analyzing and interpreting data, etc. related to each project. Specific tips to make communication more effective and efficient include:

- Be respectful of the deadlines of your project and the time constraints of your collaborators. By meeting all deadlines you acknowledge that your collaborators and their many responsibilities are important. By missing deadlines you likely adversely affect the progress of your collaborators and delay the completion of the project.
- Respond to email and phone messages in no less than 48 hours whenever possible, to ensure your collaborators know you are aware of their requests, contributions or questions.
- Let your collaborators know in advance if you will be unavailable due to travel, vacation, or other professional responsibilities. Provide an automated “away from my office” reply if you know your travel will keep you from being able to respond in a timely manner.
- Make no assumptions about the time constraints, beliefs or availabilities of your collaborators. Be as clear, direct, and specific with any communication regarding all meetings, research questions, or other concerns, delivered via email, during a virtual meeting, or in person. A great deal of time and resources are wasted and frustrations can be avoided when collaborators communicate their ideas and needs timely and explicitly, with language that treats each team member with compassion and respect.

An additional challenge we have faced has come from the lack of resources available to CAE to manage and coordinate all the research collaborations and programmatic tasks for a group the size of CATS. First, and foremost, collaborators have to get paid and reimbursed. The time involved with managing the independent contracts with individuals, and subcontracts with other institutions, has been enormous. Then layer onto this the amount of time and resources it takes to coordinate all aspects of multi-institutional research investigations, planning professional development workshops for faculty, organizing collaborator group meetings, or arranging registration and travel for professional society meetings for the whole group ...

In the end, an important lesson we have learned through our Collaboration of Astronomy Teachings Scholars program is that our most precious resource is time and that we never seem to have enough of it.

## Acknowledgements

CAE is funded through the generous contributions of the NASA JPL Exoplanet Exploration Public Engagement Program. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. We would also like to thank the thousands of students and hundreds of faculty who have made all of this possible.

## References

1. American Geological Institute; Geoscience Workforce Program 2006, Introductory geoscience enrollment in the US 2004-2005, 1-10.<sup>1</sup>
2. Bardar, E.M., Prather, E.E., Slater, T.F. & Brecher, K. 2007, Development & Validation of the Light and Spectroscopy Concept Inventory, *Astronomy Education Review* **5**(2), 85-98.<sup>2</sup>
3. Fraknoi, A. 2001, Enrollments in Astronomy 101 Courses, *Astronomy Education Review* **1**(1), 121-123.<sup>3</sup>
4. McDermott, L. C. & Redish, E. F. 1999, Resource Letter: PER-1: Physics Education Research, *American J. Physics* **67**(9), 755-767.<sup>4</sup>
5. Prather, E.E. & Brissenden, G. 2009, Development & Application of a Situated Apprenticeship Approach to Professional Development of Astronomy Instructors, *Astronomy Education Review* **7**(2), 1-17.<sup>5</sup>
6. Prather, E.E., Rudolph, A.L. & Brissenden, G. 2009, Teaching & Learning Astronomy in the 21<sup>st</sup> Century, *Physics Today* **62**(9), 41-47.<sup>6</sup>
7. Rudolph, A.L., Prather, E.E., Brissenden, G., Consiglio, D. & Gonzaga, V. 2010, A National Study Assessing the Teaching & Learning of Introductory Astronomy Part II: The Connection Between Student Demographics & Learning, *Astronomy Education Review* **9**(1), 15 pp.<sup>7</sup>

## For Further Reading

1. Bailey, J.M., Prather, E.E., Johnson, B. & Slater, T.F. 2009, College Students' Preinstructional Ideas About Stars and Star Formation, *Astronomy Education Review* **8**(1), 16 pp.<sup>8</sup>

<sup>1</sup><http://www.agiweb.org/workforce/gw-06-001.pdf>

<sup>2</sup><http://dx.doi.org/10.3847/AER2007020>

<sup>3</sup><http://dx.doi.org/10.3847/AER2001011>

<sup>4</sup><http://dx.doi.org/10.1119/1.19122>

<sup>5</sup><http://dx.doi.org/10.3847/AER2008016>

<sup>6</sup><http://dx.doi.org/10.1063/1.3248478>

<sup>7</sup><http://dx.doi.org/10.3847/AER0009068>

<sup>8</sup><http://dx.doi.org/10.3847/AER2009038>

2. Brissenden, G., Slater, T.F. & Mathieu, R.D. 2002, The Role of Assessment in the Development of the College Introductory Astronomy Course, *Astronomy Education Review* **1**(1), 1-24.<sup>9</sup>
3. Hudgins, D.W., Prather, E.E., Grayson, D.J. & Smits, D.P. 2006, Effectiveness of Collaborative Ranking Tasks on Student Understanding of Key Astronomy Concepts, *Astronomy Education Review* **5**(1), 1-22.<sup>10</sup>
4. Prather, E.E. & Brissenden, G. 2009, Clickers as Data Gathering Tools & Students' Attitudes, Motivations, & Beliefs on Their Use in this Application, *Astronomy Education Review* **8**(1), 10 pp.<sup>11</sup>
5. Prather, E.E., Rudolph, A.L., Brissenden, G. & Schlingman, W.M. 2009, A National Study Assessing the Teaching & Learning of Introductory Astronomy: Part I. The Effect of Interactive Instruction, *American J. Physics* **77**(4), 320-330.<sup>12</sup>
6. Prather, E.E., Slater, T.F., Adams, J.P. & Brissenden, G. 2008, Lecture-Tutorials for Introductory Astronomy (2nd ed.), Pearson Addison-Wesley, San Francisco CA, 134 pp. (ISBN 10: 0132392267)
7. Prather, E.E. 2005, Students' Beliefs About the Role of Atoms in Radioactive Decay & Half-life, *J. Geoscience Education* **53**(4), 345-354.<sup>13</sup>
8. Prather, E.E., Slater, T.F., Bailey, J.M., Adams, J.P., Dostal, J.A. & Jones, L.V. 2004, Research on a Lecture-Tutorial Approach to Teaching Introductory Astronomy for Non-Science Majors, *Astronomy Education Review* **3**(2), 122-136.<sup>14</sup>
9. Prather, E.E., Slater, T.F. & Offerdahl, E.G. 2003, Hints of a Fundamental Misconception in Cosmology, *Astronomy Education Review* **1**(2), 28-34.<sup>15</sup>

<sup>9</sup><http://dx.doi.org/10.3847/AER2001001>

<sup>10</sup><http://dx.doi.org/10.3847/AER2006001>

<sup>11</sup><http://dx.doi.org/10.3847/AER2009004>

<sup>12</sup><http://dx.doi.org/10.1119/1.3065023>

<sup>13</sup>[http://www.nagt.org/files/nagt/jge/abstracts/Prather\\_v53p345.pdf](http://www.nagt.org/files/nagt/jge/abstracts/Prather_v53p345.pdf)

<sup>14</sup><http://dx.doi.org/10.3847/AER2004019>

<sup>15</sup><http://dx.doi.org/10.3847/AER2002003>